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C. S. Clark, H. S. Bjorson, J. S. Fulton,
J. W. Holland, and P. S. Gartside

Institute of Environmental Health
Kettering Laboratory
University of Cincinnati
Cincinnati, Ohio 45267

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Walter Jakubowski

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16. ABSTRACT

Although pathogenic bacteria and viruses are reduced in numbers by the high temperatures achieved in composting, conditions are ideal for the proliferation of thermophilic microorganisms, such as Aspergillus fumigatus. The dust at sludge compost sites also contains significant quantities of lipopolysaccharide (LPS) or endotoxin. During 1979-81 a prospective epidemiological health study was conducted of compost workers in Camden (NJ), Philadelphia (PA), Washington, D.C. and Beltsville (MD) to evalute the health effects related to exposure to LPS, A. fumigatus and other microorganisms. The study included environmental monitoring and a clinical and serological evaluation of exposed and control workers. Among the findings to date are an increase in antibody against LPS and A. fumigatus in workers in the Washington-Beltsville area in 1979. Anterior nares and oropharyngeal cultures positive for A. fumigatus were more common among compost workers. The concentration of C-reactive protein was higher among compost workers at one site. Physical examinations revealed an excess of abnormal skin, ear, nose and eye conditions among compost-exposed workers. One worker had an ear infection with A. niger and an abnormal chest x-ray possibly related to exposure to dust at the compost site. Although infection with Legionella pneumonia was not different among exposure groups, it was different by geographic area, with study participants in the Philadelphia-Camden area having significantly more seroconversions than those in the Washington-Beltsville area.

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ABSTRACT

The composting of wastewater treatment plant sludge has increased considerably in the past several years in the U.S.A. and elsewhere. As recently as 10 years ago sludge composting in the U.S.A. was practised mainly by Los Angeles County, using the windrow method. The development of the aerated pile method by the U.S. Department of Agriculture at Beltsville, MD., prohibitions against ocean dumping, and the increased cost of alternative sludge treatment methods have led to a rapid expansion in systems for composting sludge prior to its land application. Successful year round outdoor composting sites are operating in many areas of the Northeast and Midwest. Although pathogenic bacteria and viruses are effectively reduced in numbers by the high temperatures achieved in composting, conditions are ideal for the proliferation of thermophilic microorganisms, such as the fungus Aspergillus fumigatus. The dust at sludge compost sites also contains significant quantities of lipopolysaccharide (LPS) or endotoxin, derived from viable and nonviable gram-negative bacteria present in the sludge. The LPS is not destroyed by the temperatures attained during composting and thus represents a potential health risk to workers engaged in sludge composting, and possibly to users. During 1979-81 a prospective epidemiological health study was conducted of compost workers in Camden (NJ), Philadelphia (PA), Washington (D.C.) and Beltsville (MD) to evaluate the health effects related to exposure to LPS, A. fumigatus and other pathogenic microorganisms. The study included environmental monitoring and a clinical and serological evaluation of exposed and control workers. The environmental monitoring consisted of workplace air sampling for A. fumigatus and other thermophilic fungi, total bacteria, total coliforms, fecal coliforms and fecal streptococci. The clinical and serologic evaluation consisted of physical examinations, chest X-rays, illness and medical history questionnaires, liver and kidney function profiles, anterior nares and oropharyngeal cultures, determination of antibody directed against LPS prepared from compost samples, skin testing with A. fumigatus antigen, quantitation of IgG, IgM, IgA and IgE, determination of C-reactive protein, levels of C3 and CH_{50}, complete blood count with differential and pulmonary function tests. Among the findings to date are an increase in antibody directed against LPS and A. fumigatus in exposed workers in the Washington-Beltsville area in 1979. Anterior nares and oropharynneal cultures positive for A. fumigatus were more common among

[1] Institute of Environmental Health, Kettering Laboratory, University of Cincinnati, Ohio, U.S.A. 45267

compost workers. The concentration of C-reactive protein was higher among compost workers at one of the study sites. Physical examinations revealed an excess of abnormal skin, ear, nose and eye conditions among compost-exposed workers which may be related to compost exposure. One worker was found to have an ear infection with A. niger and an abnormal chest X-ray possibly related to exposure to dust at the compost site. Although infection with Legionella pneumophila as determined by seroconversion to one or more serotypes, was not different between the exposure groups, it was different by geographic area, with study participants in the Philadelphia-Camden area having significantly more seroconversions than participants in the Washington-Beltsville area.

INTRODUCTION

Personnel employed at wastewater treatment plant sludge composting operations are exposed to a variety of viable gram-negative bacteria, and fungi as well as microbial products such as endotoxin (lipopolysaccharide (LPS)) in their work environment. This investigation was designed to evaluate by clinical, microbiological and immunological methods the health effects related to exposure to these nonviable substances and viable microorganisms present in dust arising from the composting of sludge. The study was conducted during 1979-81 at sewage sludge composting facilities in Camden (NJ), Philadelphia (PA), Beltsville (MD) and Washington (D.C.).

BACKGROUND

Municipal wastewaters may contain a variety of potentially pathogenic microorganisms. Conventional wastewater treatment does not completely destroy these microorganisms, many of which are concentrated in the sludge. Therefore, sludge should be stabilized by a method such as composting prior to its application on land. Composting is a thermophilic aerobic decomposition process. The heat generated during the composting process has been shown to effectively reduce the numbers of viable microorganisms present. Two types of composting processes are currently in use — windrow and forced aeration pile systems. The windrow system consists of long, low piles which are aerated by periodic turning. The forced aeration pile system consists of a stationary compost pile constructed over a network of porous pipe attached to a blower which draws air through the pile. Temperatures in the range of 55°-65°C are usually attained during the composting process provided the mixing or aeration is efficient. One of the most important objectives of composting is to obtain these high uniform temperatures throughout the system for a period of time long enough to heat up the entire mass. When this objective is fulfilled the composting process will inactivate most microorganisms including viruses (Burge and Millner 1980). However the heat generated will not detoxify the LPS of gram-negative bacteria and other microbial products present in the compost.

Heat generated during composting results in temperatures ideal for the proliferation of many thermophilic microorganisms such as actinomycetes, mucorales and Aspergillus fumigatus. Therefore, compost workers may be exposed not only to the enteric pathogenic microorganisms present in raw sludge (also referred to as primary pathogens since they are capable of initiating an infection in an apparently healthy individual) but also to the thermophilic fungi and actinomycetes that proliferate during composting.

Millner et al. (1980) demonstrated that the dispersal of fungal spores from composting sewage sludge and wood chip mixtures in Washington (D.C.) and Beltsville (MD) behaved as a Gaussian plume. A major source of airborne spores was found to be the front-end loader which was estimated to aerosolize 4.6×10^6 A. fumigatus spores/second when moving and dropping compost. At the Beltsville compost site airborne concentrations of A. fumigatus between 3 and 30 meters downwind of a compost pile being agitated by a front-end loader were reported to range from 1400 to 3100 cfu/m^3. Fifteen minutes after agitation, levels were less than 40 cfu/m^3.

Aspergillus spp. are ubiquitous in the environment of most countries of the world. The fungus grows well on a variety of substrates, including stored hay or grain, decaying vegetation, soil, and dung. A. fumigatus grows well at 45°C or even higher, making it one of the most common microorganisms found at compost sites (Millner et al. (1977)). A. fumigatus, and other species of Aspergillus have been shown to be capable of causing disease in both normal and compromised individuals. Therefore, workers involved in the composting process may be exposed to potential health risks due to their exposure to high concentrations of A. fumigatus spores. In addition, the fungus Aspergillus flavus which produces aflatoxin, one of the most potent known human carcinogens, may increase in numbers during composting.

The term "aspergillosis" has been used to describe illness attributed to antigenic stimulation, colonization, or tissue invasion by Aspergillus spp. Aspergillosis is thought to be acquired by inhalation of airborne spores. These spores (conidia) are small enough (2.5-3.0 um for A. fumigatus) to reach alveoli or to gain entrance to paranasal sinuses. The disease varies in severity from an incidental, saphrophytic relationship with the host to a fulminating, fatal infection.

The dose (number of cfu), portal of entry, and the immune status of the host are thought to be major determinants in the course of the infection caused by A. species. Immunosuppressed patients are thought to be at a greater risk to infection by A. fumigatus (Ripon 1974). Serious and often fatal invasive infections caused by A. fumigatus have been reported in immunosuppressed patients following kidney transplanation and in patients with leukemia or lymphoma receiving chemotherapy. Individuals receiving antibiotics or adrenal cortical hormones have also been shown to have a higher

incidence of mycotic infections. Additional predisposing factors to aspergillosis appear to be the presence of malignant or other debilitating disease, granulocytopenia, other infections, pneumonitis and underlying pulmonary disease (Ripon 1974).

Exposure of atopic individuals, who have a history of asthma, to spores of A. fumigatus may result in a disease known as allergic bronchopulmonary aspergillosis. Colonization of the bronchi in these patients with Aspergillus results in episodic bronchial plugging which appears to lead to areas of sacular bronchiectasis. These patients may produce sputum plugs which often reveal fungal mycelia on microscopic examination. Laboratory abnormalities in these patients include significant eosinophilia of blood and sputum, marked elevation of total serum IgE, and serum precipitating antibody to Aspergillus antigens. These patients usually have an immediate type skin response to Aspergillus antigen. Persistent bronchopulmonary aspergillosis may result in irreversible complications such as bronchiectasis and pulmonary fibrosis.

The pathophysiology of allergic bronchopulmonary aspergillosis is thought to be mediated by a combination of both Type I and Type III immunologic reactions. IgE-sensitized mast cells in the bronchi react with antigens from Aspergillus colonizing the bronchi. This interaction leads to release of histamine, a slow-reacting substance of anaphylaxis, and eosinophilic chemotactic factors by the mast cells. The mediators released by mast cells result in bronchospasm, increased permeability of the bronchial mucosa, absorption of Aspergillus antigen into the circulation, and pulmonary and peripheral blood eosinophilia. The absorbed Aspergillus antigen can react with IgG, resulting in the formation of antigen-antibody complexes and complement fixation. This in turn may lead to chronic inflammation in the bronchi and peribronchial tissues with eventual bronchial destruction, bronchiectasis, and pulmonary fibrosis.

Due to the wide distribution of Aspergillus spp. in the environment, exposure to Aspergillus must be nearly universal but disease, either invasive or allergic, in uncommon. As indicated above, a complex interaction between host factors and the challenge dose of fungal spores appears to determine the course of events which follow exposure to Aspergillus. The dust at composting sites also contains significant quantities of LPS derived from gram-negative microorganisms which are present in sludge (Clark et al. 1982).

In a study at a compost plant using a mixture of household refuse and wastewater sludge Lundholm and Rylander (1980) reported symptoms of nausea, headache, fever or diarrhea in 6 of 11 compost plant workers compared to only two of the 41 water treatment plant employees who served as controls. Endotoxins were suspected of playing an important role.

EXPERIMENTAL PROCEDURES

The clinical and serologic evaluation of workers exposed to dust at the composting site included: (1) comprehensive history, (2) physical examination and chest X-ray of selected particpants, (3) illness monitoring, (4) complete blood count with differential, (5) determination by an enzyme linked immunosorbent assay (ELISA) of IgG antibodies directed against antigen prepared from Aspergillus fumigatus and determination of antibody against A. fumigatus antigen by counter immuno electrophoresis (CIE) in sera obtained from the study participants, (6) determination of IgG antibodies in workers' sera directed against LPS prepared from compost by the ELISA technique, (7) pulmonary function tests, (8) determination of C-reactive protein (CRP) and C3 in workers' sera, (9) determination of serum renal and liver profiles, and (10) determination of antibody directed against the H and M antigens of Histoplasma capsulatum in workers' sera. Health questionnaires, nose and throat cultures and sera for the serologic tests were obtained 8 times during the study. Air monitoring for A. fumigatus and other thermophilic fungi was also conducted.

Population Groups

Workers in the study were divided into 3 exposure categories: category I - workers directly engaged in composting; category II - workers occasionally involved in composting or whose job locations are within 100 m of a composting operation; category III - workers not involved in compost activities and whose job activities are greater than 100 m from composting. A total of about 250 workers participated in the study and were approximately equally divided between the exposed groups and between the Camden-Philadelphia and Washington-Beltsville areas. In Camden (NJ) the compost unit is located at the main 30 MGD (1.31 m^3/s) wastewater treatment plant. In Philadelphia, PA the compost plants are located at the Northeast (130 MGD, 5.7 m^3/s)) and Southwest (136 MGD, 5.96 m^3/s) Wastewater Treatment Plants. In Washington (D.C.) the compost plant is located at the 300 MGD (13.14 m^3/s) Blue Plains Wastewater Treatment Plant. The compost facility in Beltsville (MD) located at the Beltsville Agricultural Research Center, treats some of the sludge produced at the Blue Plains Wastewater Treatment Plant. About one-half of the compost workers in Philadelphia and all compost workers at Blue Plains, were employees of private firms contracted by the respective municipalities on a yearly basis to perform composting functions. Workers in exposure category II were recruited from locations near the compost plants. Exposure category III workers in Philadelphia were located at a third wastewater treatment plant, the Southeast Plant; in Camden at the Baldwin Run Wastewater Treatment Plant and in Washington (D.C.) from a wastewater pumping station and from the District of Columbia Water Services Department. The latter group was substituted for the Piscatsway (MD) wastewater treatment plant worker group which was used as a control group in 1979. This change was made to provide a

control group that had no occupational exposure to viable and nonviable microorganisms present in aerosols produced from wastewater.

During the period of the overall investigation 26 exposure category I workers, 39 exposure category II workers, and 42 exposure category III workers underwent a physical examination. The examinations were performed by licensed physicians and the results were recorded on a standard form.

Chest roentgenograms were obtained on 18 exposure category I workers, 26 exposure category II workers, and 34 exposure category III workers one time during the first year of the study. The chest roentgenograms were performed at hospitals located geographically near each facility involved in the study. All roentegenograms were evaluated by J.F. Wiot, M.D., Chairman and Professor of Radiology, Department of Radiology, University of Cincinnati College of Medicine, Cincinnati, OH.

Serologic Tests

Serum for determination of antibody directed against Aspergillus spp. antigens was collected from study participants during each visit as described above. Precipitating antibody directed against A. fumigatus, A. flavus, A. carneus, and A. niger antigens (Aspergillin, Meridian Diagnostics, Cincinnati, OH) in the serum of the study participants was measured quantitatively using the CIE technique.

Detection of antibody directed against the H and M antigens of Histoplasma capsulatum was performed using an antigen that was a mycelial phase culture filtrate of H. capsulatum (Histophasmin, Meridian Diagnostic, Inc.). Antibody in workers sera directed against histoplasmin was detected by the CIE technique. A control serum, from goats, containing antibodies against the "H" and "M" antigens of histoplasmin was placed in a well adjacent to the serum to be tested. The presence of a M precipitin band was considered presumptive evidence for infection with H. capsulatum.

Antigen was also prepared from A. fumigatus grown in sabouraud dextrose broth (Difco Laboratories, Detroit, MI) at 31°C for 5 weeks. The mycelium was separated from the culture medium by Buchner filtration followed by Seitz filtration to remove any viable fungal elements. The filtrate was concentrated 8X by ultra filtration using an Amicon PM 30 membrane (Amicon Corporation, Lexington, MA). The concentrated culture filtrate was precipated with 8 volumes of acetone at 4°C as described by Coleman and Kaufman (1972). The precipitate was pelleted by centrifugation at 12,000 x g at 4°C and the precipitate was washed with acetone at 4°C. The precipitate was dissolved in distilled water, lyophilized, and stored at -60°C. This antigen preparation was used for detection of antibody in sera using the ELISA technique.

LPS was prepared from 500 g samples of cured screened compost obtained from the Camden and Blue Plains compost facilities by the phenol-water extraction procedure of Westphal and Jann (1965). The combined water extracts were precipitated with ethanol. The ethanol precipitated LPS was dissolved in distilled water and ultra-centrifuged at 110,000 x g for 3 hurs at 4°C. The resulting pellet was dissolved in distilled water, lyophilized and stored at -60°C. The LPS preparations were used for detection of antibody in sera using the ELISA technique.

Determination of Antibody in Serum Directed Against A. fumigatus and LPS Antigens Using the ELISA

An ELISA was used for the determination of antibody directed against A. fumigatus and LPS antigens. The ELISA used was a solid phase immunoassay as described by Engvall and Perlmann (1971) and modified for detection of antibodies directed against LPS by Bruins et al. (1979). All determinations were performed in triplicate.

CRP, C3, IgM, IgA and IgG concentrations in serum were determined by radial immunodiffusion using a minor modification of the method of Mancini et al (1965). Antiserum and normal reference serum for the B antigen of C3 was generously supplied by Dr. A. Bjornson. Antiserum and normal reference serum for Ig and CRP were obtained from Behring Diagnostics, Sommerville, NJ.

The concentration of total IgE in sera obtained from workers participating in this study was determined by radioimmunoassay using the Pharmacia Diagnostics (Piscataway, NJ) Phadebas IgE PRIST kit. All determinations were performed in duplicate.

Hemolytic complement was determined by the method of Mayer (1971). Results were expressed as the units/ml of serum which resulted in 50% lysis of sensitized sheep erythrocytes (CH_{50} units/uL).

A. fumigatus Colonies in Throat and Anterior Nare Cultures

Cultures of the throat and anterior nares of the workers participating in the study were obtained with a dry cotton-tipped applicator (Culturette II, Marian Scientific Corp., Kansas City, MO). The cultures were stored on dry ice until processed. The cotton tipped applicator were immersed in 2.0 mL of sterile saline and vortexed vigorously for 60 seconds to elute any fungal elements contained on the applicator. After elution, the number of A. fumigatus contained on the applicator was determined semi-quantitatvely by the dilution plate count method on Czapek-Dox Bile agar plates containing streptomycin, chloramphenicol and penicillin (Difco Laboratories).

Air Monitoring

Viable particle collection from air samples was performed using the six-stage Andersen cascade impactor. Pumps were calibrated at 28.3 L of air per minute as recommended. The samplers were mounted on tripods such that samples were collected at a height of 1.5 m. Sampling times were adjusted in an attempt to obtain colony numbers which were optimal for counting. Total colony counts for bacterial and fungal plates were obtained by direct colony count, unless excessive colony numbers precluded this procedure. If colony numbers precluded counting all colonies, the colonies on 1/4 or 1/2 the plate were counted and the count was multiplied by the appropriate number to obtain a total plate count.

Bacterial samples were collected on Trypticase soy agar (TSA) manufactured by Baltimore Biological Laboratories (BBL), Cockeysville (MD). Fungal samples were collected on modified Czapek-Dox medium with streptomycin, chloramphenicol and penicillin added to retard bacterial growth (Clark et al. 1980). Aerosol samples obtained on TSA plates were incubated at 36°C for 24 hours. At the end of the incubation period, total bacterial counts on the TSA plates were determined; the plates were then replicate plated onto three different types of media: KF streptococcal agar (BBL), M - FC agar (BBL), and M-Endo agar (BBL) (APHA et al. 1976).

The purpose of replication onto M-FC agar was to determine the presence or absence of fecal coliforms. These plates were incubated at 44.5°C for 24 hours and the blue to blue green colonies were transferred to a Lauryl sulfate broth (BBL) which was incubated 24-48 hours at 37°C and to EC broth (BBL) which was incubated for 24 hours at 44.5°C. Growth with gas confirmed the presence of fecal coliforms.

Total coliforms were determined by replicate plating the TSA plates onto M-Endo agar (BBL) and incubated at 37°C for 24 hours. The colonies with a green sheen were picked to Lauryl sulfate broth and Brillant green bile broth (BBL). These media were incubated at 37°C for 48 hours, $\pm$ 3 hours. Growth with gas confirmed the presence of coliforms.

Fungal plates, upon reaching the laboratory, were incubated at 44.5°C for 48 hours and total plate counts were performed. The microorganisms were separated into A. fumigatus and "other thermophilic microorganisms" on the basis of microscopic examination, colony color and morphology.

RESULTS

Preliminary results of the 1979 phase of this study were presented earlier, Clark et al. (1980). What follows is an interim report on available results for the entire 1979-81 period of the study.

Air Monitoring

The primary purpose of the air monitoring was to compare the relative exposure levels at the five compost sites involved in the study. Overall, air concentrations of A. fumigatus were higher in the Camden-Philadelphia area than in Washington-Beltsville. Fecal streptococci levels were generally higher than fecal coliforms. Other thermophilic fungi and total bacteria were usually found in higher levels in the Washington-Beltsville area than in Camden-Philadelphia.

Cultures of Anterior Nares and Throat Swabs

The percentage of workers with cultures positive for A. fumigatus differed among the 3 exposed groups; compost workers (70%), intermediate exposure (20%), and controls (5%). The differences among the groups in A. fumigatus colonies supports the exposure category designations. Even though viable A. fumigatus spores are ubiquitous, their concentration around compost sites is sufficiently elevated above background to result in a higher degree of colonization among compost-exposed workers.

Physical Examinations

Results of the physical examination were recorded on a standard form designed to detect conditions that were possibly related to compost exposure. The physical examinations revealed 3 groups of findings possibly related to compost exposure. These abnormal findings were observed more frequently in the compost and intermediate exposed group than in controls (Table 1). Evidence of acute or chronic inflamation of eyes and nose that is possibly compost-related was found in 5 compost workers, 8 intermediate-exposed workers and in none of the controls. Nasal disorders were only present in workers from one of the cities. Abnormal skin conditions were detected in 3 compost workers, 8 intermediate-exposed workers and in none of the controls. Three of the 4 workers with ear problems had acute infections during compost employment. For one the infection has persisted for several years with resulting destruction of the right ear drum. A chest X-ray of this worker revealed diffuse interstitial lung disease which may be related to exposure to dust at the compost site.

The interpretation of the physical examination results should be treated with caution because of the relatively few workers involved and the geographic differences in the nasal disorders.

At a compost plant not included in the physical examinations, 5 of 15 workers reported skin rashes earlier this year. Three were reported to have been related to fungal infections.

Table 1. Significant results of physical examinations.

Abnormal Findings	Compost Workers	Intermediate-exposed	Control
number of workers	26	39	42
Evidence of Acute or Chronic Inflamation of Eyes and Nose:			
Orbitopalpebral grooves	0	1	0
Inferior turbinates (engorged)	5	7	0
Evidence of Acute or Healed Ear Infection	2	2	0
Skin:			
Evidence of Active or Healed Skin Abscesses, Carbuncles or Furuncles	1	4	0
Evidence of Other Cutaneous Infections	1	3	0
Other Abnormalities of Skin	1	1	0

Antibody to A. fumigatus and Compost-derived LPS

Serum from participants was tested by the ELISA method for antibody to A. fumigatus and to compost LPS from Camden and Beltsville. Analysis of results from the 1979 phase of the study revealed higher antibody response to Beltsville compost-derived LPS in compost workers in the Washington, D.C.-Beltsville area than in the intermediate-exposed and control workers. Analysis thus far performed on 1980-81 data suggest that these relationships did not persist. No consistent increase in antibody to A. fumigatus has been detected in compost-exposed workers. Antibody response to LPS derived from the two compost materials has been found to be significantly correlated in all exposure groups in both the Philadelphia-Camden and Washington-Beltsville

areas, indicating similarities in biological activity of the compost samples. Similar correlations were detected between antibodies to A. fumigatus and LPS from compost except among compost and intermediate-exposed workers in the Washington-Beltsville areas, who had lower exposures to A. fumigatus than other compost workers.

Pulmonary Function

Pulmonary function tests were conducted on Friday morning and Friday afternoon, and Monday morning and Monday afternoon to evaluate lung function after exposure and non-exposure to the work environment. Forced vital capacity (FVC), forced expired volume in one second (FEV_1)k, and forced expiratory flow (FEF_{25-75}), a measure of the 50% of the forced vital capacity after the first 25%, were determined.

A total of 98 sets of Monday/Friday data, collected between May 1979 and January 1982, were analyzed; 40 on compost workers, 29 on intermediate-exposed workers, and 29 on controls. Results demonstrate statistically significant differences at p less than 0.05 only between the FVC tracings from Friday evening and Monday morning in compost workers with the average FVC higher on Friday evening than on Monday morning. No statistically significant results (p less than 0.05) are observable between any other paired values in any of the groups. Results indicate that the forced vital capacity in compost workers recorded on Fridays is different than the value on Mondays, and that non-exposure to compost over a 2-day weekend may be a factor, as this difference is not demonstrated in workers with less intense or no exposure to compost.

CRP, C3, Complement and Immunoglobulin Analyses

The mean concentrations of immunoglobulins G, M, A, and E in serum samples obtained from workers in the compost, intermediate-exposed and control worker do not indicate significant differences among the three exposure groups. Simiarly, mean concentration of C-reactive protein (CRP), C3, and hemolytic complement activity (CH_{50}) in serum samples obtained from workers do not appear to differ between the groups.

In an analysis of 1979 data alone, the compost workers in Beltsville had somewhat higher values of CRP than in intermediate-exposed workers in Beltsville ($p = 0.05$).

Histoplasma capsulatum

Three hundred and eighty-nine serum samples were tested by counter-immunoelectrophoresis (CIE) for the presence of precipitins against: (1) the H and M antigens of Histoplasma capsulatum and, (2) a pool of antigens derived

from A. fumigatus, A. flavus, A. carneus, and A. niger. There were no precipitins detected in the sera tested against any of these antigens.

Legionella pneumophila

Legionella pneumophila antibody titers were measured in paired sera from 83 compost and intermediate-exposed workers and 38 controls, using the indirect fluorescent antibody assay and antigens from serogroups 1 through 4. In addition, single specimens were analyzed from 5 compost workers and 9 intermediate-exposed workers. Analyses were performed in the laboratory of Dr. Calvin C. Linnemann Jr. of the University of Cincinnati College of Medicine. Six men had fourfold increases in antibody. Two of the workers were from the high exposure group, 2 from the partially exposed group, and 2 controls. Six additional men had antibody titers of greater than or equal to 1:128 to at least one of the four serogroups, but did not have a significant increase in antibody. These 6 included 3 workers and 3 controls. These results indicate that there appears to be no increased risk of Legionella pneumophila infection in the compost workers studied. It is interesting that the overall infection rate as indicated by rising antibody titers is 4.9%. This is much higher than the infection rate noted in the previous study of wastewater workers, 0.8% per year (Clark et al. 1981).

A summary of the fourfold and greater titer level rises by area and exposure group (Table 2) reveals no apparent difference between exposure groups. However, on an area basis there are more titer level rises in the Camden-Philadelphia area than in Washington-Beltsville. Camden-Philadelphia has a higher percentage of workers with titer levels of greater than or equal to 1:128 than the Washington-Beltsville area, 13% and 3%, respectively.

DISCUSSION

Cultures of the throat and anterior nares of workers at compost sites were frequently positive for Aspergillus fumigatus; similar cultures obtained from workers in the intermediate-exposure group and controls were generally negative for A. fumigatus. These results suggest that fungal spores in the environment at the compost site may have resulted in the colonization of the upper respiratory tracts of the workers at the compost sites studied.

The finding of higher rates of abnormal skin, ear and nose conditions among compost and intermediate-exposed workers, suggests that exposure to compost may be having an adverse impact on the health of the workers so exposed. These results justify a continuation of health studies of workers engaged in the composting of waste materials. The lowered FVC among compost workers on Monday morning compared to Friday afternoon is difficult to explain since weekend absence from a pulmonary irritant would be more likely to have the opposite effect.

Specific antibody directed against the H and M antigens of H. capsulatum or a pool of antigens prepared from A. fumigatus, A. flavus, A. carneus, and A. niger was not detected in the sera obtained from any of the study participants. These results suggest that serologically-detectable infections caused by these fungi were uncommon among the workers studied, despite the exposure of compost workers to high numbers of fungal spores at the compost site.

Table 2. 4-fold and greater titer level increases to Legionella pneumophila antibody.

Group	Number of Workers Camden-Philadelphia	Washington-Beltsville	Total
Compost			
# tested	35	9	44
# titer level rises	2	0	2
Intermediate-Exposed			
# tested	15	24	39
# titer level rises	2	0	2
Control			
# tested	16	22	38
# titer level rises	2	0	2
Total			
# tested	66	55	121
# titer level rises	6	0	6

The effects observed in this study may be due to the nature of the compost process itself and therefore may not be related specifically to the use of wastewater sludge in the composting operations.

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